National Geochemical Reconnaissance

Geological Survey of Canada Open File 3716

Reanalysis of 1775 lake sediments from Regional Surveys on Central Baffin Island

Parts of NTS 27B, 27C, 37A and 37D

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GEOLOGICAL SURVEY OF CANADA OPEN FILE 3716

NATIONAL GEOCHEMICAL RECONNAISSANCE REANALYSIS OF 1,775 LAKE SEDIMENTS FROM REGIONAL SURVEYS ON CENTRAL BAFFIN ISLAND, NUNAVUT 1999

PARTS OF NTS 27B, 27C, 37A, AND 37D

Hangar at former U.S. military base located on Longstaff Bluff, Baffin Island, Nunavut.

Open File 3716 represents a contribution to the Central Baffin Partnership Project.

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FRONTISPIECE Hangar at former U.S. military base located on Longstaff Bluff, Baffin Island.

Cover Design: Sue Davis, Regional Geochemistry and Geophysics Subdivision

GSC OPEN FILE 3716
REANALYSIS OF 1775 LAKE SEDIMENTS FROM SURVEYS ON CENTRAL BAFFIN ISLAND, NUNAVUT (NORTHWEST TERRITORIES)
PARTS OF NTS 27B, 27C, 37A AND 37D

INTRODUCTION

Open file 3716 presents data for gold and 25 additional elements obtained by reanalyzing lake sediments collected in 1978 from 1,774 sites on central Baffin Island, Nunavut (Northwest Territories). Original analytical data from Geological Survey of Canada (GSC) open files 566, 567 and 568 (released in 1979) for 11 elements plus loss-on-ignition in sediments, and uranium, pH and fluoride values in concomitant waters, are also included in this open file.

The GSC under the terms of the Federal Uranium Reconnaissance Program carried out the original reconnaissance surveys. Anomalous levels of arsenic in lake sediments revealed by these surveys sparked renewed interest in the area, and in 1998, the Qikiqtaaluk Corporation, through the North Baffin Partnership Program, agreed to provide funds to reanalyze lake sediments collected in 1978.

The purpose of the reanalysis was to confirm the original arsenic values and to provide supplementary data in the form of an additional 25 elements derived from non-destructive instrumental neutron activation analysis.

Drainage sediment surveys carried out since 1975 in the Northwest Territories/Nunavut are shown in Figure 1. Analytical results contribute to a national geochemical database for resource assessment, mineral exploration, geological mapping and environmental studies. Sample collection, preparation and analytical methods are strictly specified and carefully monitored to ensure consistent and reliable results regardless of the area, the year or the analytical laboratory.

COLLECTION PROCEDURES AND SAMPLE MANAGEMENT (ORIGINAL SURVEYS)

Helicopter-supported sample collection was carried out during the summer of 1978. Lake sediment and water samples were collected at an average density of one sample per 13 km^2 throughout the 25,900 square kilometres covered by the survey.

Sample site duplicate samples were routinely collected in each analytical block of twenty samples. Field observations were recorded on standard forms used by the Geological Survey of Canada (Garrett, 1974).

Site positions were marked on 1:250 000 scale NTS maps in the field and later digitised at the Geological Survey in Ottawa to obtain Universal Transverse Mercator (UTM) co-ordinates. The dominant rock types in the lake catchment basins were identified on appropriate geological maps used as the bedrock geological base on NGR maps.

In Ottawa, field dried samples were air-dried, crushed and ball-milled. The minus 80 mesh (177 micron) fraction was obtained and used for

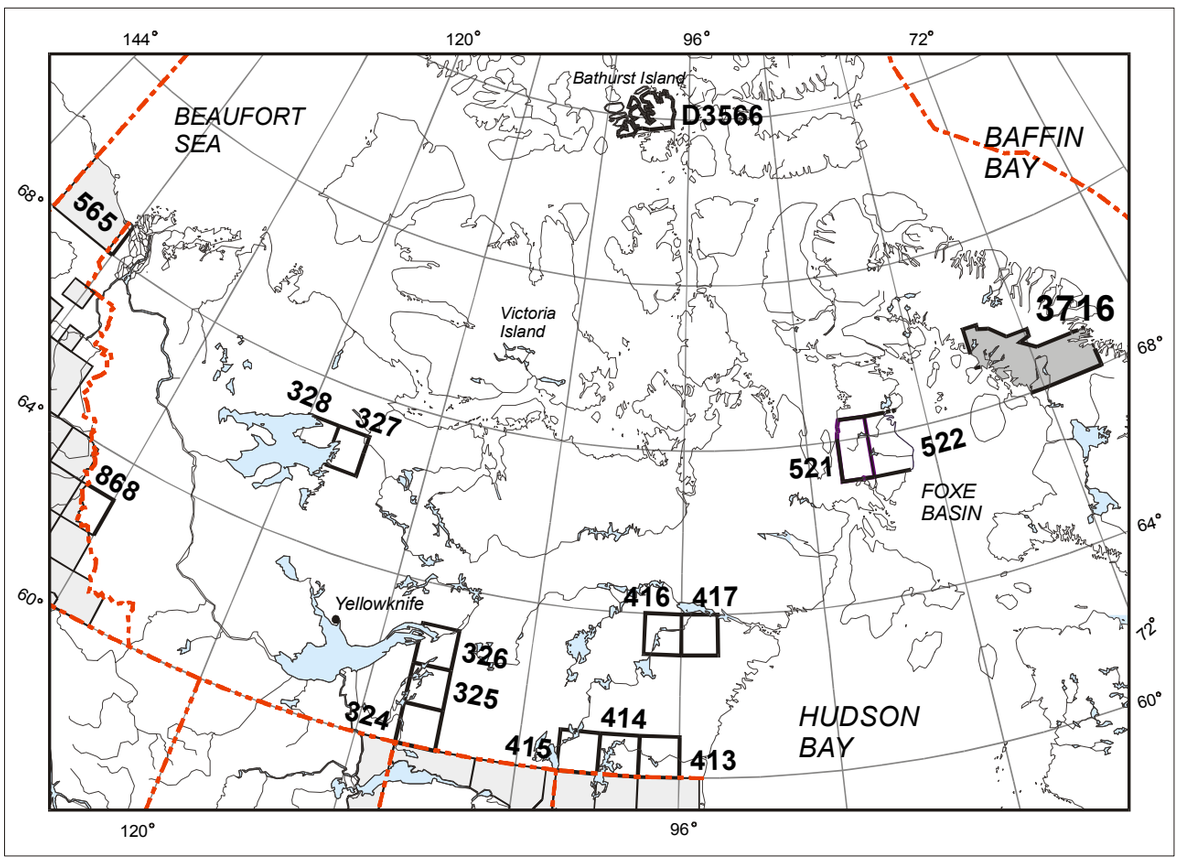

Figure 1. Areas of the Northwest Territories and Nunavut covered by NGR geochemical surveys, with current GSC open file numbers.

subsequent analyses. At this time, control reference and blind duplicate samples were inserted into each block of twenty sediment samples. For the water samples, only control reference samples were inserted into the block. There were no blind duplicate water samples. Additional lake sediment material required for INAA analyses was taken from archive storage. Particle reduction was accomplished using a ceramic puck mill.

Analytical data from labs were monitored for reliability with standard methods used by the Applied Geochemistry and Geophysics Subdivision at the GSC.

ANALYTICAL PROCEDURES

Instrumental Neutron Activation Analysis (INAA)

Weighed and encapsulated samples are packaged for irradiation along with internal standards and international reference materials. Samples and standards are irradiated together with neutron flux monitors in a two-megawatt pool-type reactor. After a seven-day decay period, samples are measured on a high-resolution germanium detector. Computer control is achieved with a Microvax II computer. Typical counting times are 500 seconds. Elements determined by INAA include: Ag, As, Au, Ba, Br, Cd, Ce, Co, Cr, Cs, Eu, Fe, Hf, Ir, La, Lu, Mo, Na, Ni, Rb, Sb, Sc, Se, Sm, Sn, Ta, Tb, Te, Th, U, W, Yb, Zn, and Zr. The sample weights are also reported. Data for Ag, Cd, Ir, Mo, Ni, Se, Sn, Te, Zn, and Zr are not published because of inadequate detection limits and/or precision.

Atomic Absorption Spectroscopy (AAS) and Other Analyses

For the determination of Zn, Cu, Pb, Ni, Co, Ag, Mn and Fe, a 1-g sample was reacted with 6 ml of a mixture of 4M HCl and 1M HNO_3 in a test tube overnight at room temperature. After digestion, the test tube was immersed in a hot water bath at room temperature and brought up to 90 degrees C and held at this temperature for 2 hours with periodic shaking. The sample solution was then diluted to 20 ml with metal-free water and mixed. Zn, Cu, Pb, Ni, Co, Ag, Mn and Fe were determined by atomic absorption spectroscopy using an air-acetylene flame. Background corrections were made for Pb, Ni, Co and Ag.

Arsenic was determined by atomic absorption using a hydride evolution method wherein the arsenic was evolved as AsH_3 and passed through a heated quartz tube in the light path of an atomic absorption spectrophotometer. The method is described by Aslin (1976).

Molybdenum was determined by atomic absorption spectroscopy using a nitrous oxide acetylene flame. A 0.5 g sample was reacted with 1.5 ml concentrated HNO3 at 90 degrees C for 30 minutes. At this point 0.5 ml concentrated HCl was added and the digestion continued at 90 degrees C for an additional 90 minutes. After cooling, 8 ml of 1250 ppm Al solution were added and the sample solution diluted to 10 ml before aspiration.

Loss-on-ignition was determined using a 500 mg sample. The sample, weighed into a 30 ml beaker, was placed in a cold muffle furnace and brought up to 500° C over a period of two to three hours. The sample was held at this temperature for four hours, then allowed to cool to room temperature for weighing.

Uranium was determined using a neutron activation method with delayed neutron counting. Boulanger et al. (1975) provides a detailed description of the original method. In brief, a 1-gram sample was weighed into a 7-dram vial, capped and sealed. The sample was irradiated in a Slowpoke reactor with an operating flux was 10^{12} neutrons/cm^2/second. The samples were pneumatically transferred from an automatic loader to the reactor, where each sample was irradiated for 60 seconds. After irradiation, the samples were again transferred pneumatically to the counting facility where after a 10 second delay the sample was counted for 60 seconds with six BF3 detector tubes embedded in paraffin. Following counting, the samples were automatically ejected into a shielded storage container.

Calibration was carried out twice a day or as a minimum using natural materials of known uranium concentration.

Water Analyses

Uranium, fluoride and pH were determined in lake water samples. Upon receiving a batch of samples, fluoride and pH were determined by specific ion electrode and glass-calomel combination electrode, respectively. After these two determinations were completed, the remaining water in the sample bottle (approx. 225 ml) was acidified with 3 ml concentrated HNO_3.

Two weeks after acidification, a 5 microlitre aliquot of the sample was then removed for the determination of uranium by fission track analysis. The two-week waiting period was to ensure that all precipitated uranium was redissolved.

To determine uranium, sample aliquots were placed on a polycarbonate tape and dried. The tape was then irradiated in a nuclear reactor at McMaster University (Hamilton) for one hour in a flux of 10^{13} neutrons/cm^2/sec. The tape was subsequently etched with 25% NaOH solution and the fission tracks were counted with an optical counter fitted to a microscope. The number of tracks was proportional to the uranium concentration. Each tape contained its own calibration standards, blanks and sample duplicates.

Hydrogen ion activity (pH) was measured with a Beckman combination electrode and a Model 401 Orion specific ion meter.

Fluoride in lake water samples was determined using an Orion fluoride electrode and a Model 401 Orion specific ion meter. Prior to measurement, an aliquot of the sample was mixed with an equal volume of a modified TISAB (total ionic strength adjustment buffer). The modification consisted of adding 60 ml of 8M KOH solution to the buffer. This permitted the reanalysis of fluoride in acidified water samples when required. When this analysis was necessary, acidified standard solutions were used for calibration.

Table 1 provides a summary of analytical data and methods.

Table 1. Summary of Analytical Data and Methods

ELEMENT		DETECTION LEVEL		METHOD
SEDIMENTS:				
Ag	Silver	0.2	ppm	AAS
As	Arsenic	1	ppm	AAS
As	Arsenic	0.5	ppm	INAA
Au	Gold	2	ppb	INAA
AuS1	Gold (1st split)	2	ppb	INAA
AuS2	Gold (2nd split)	2	ppb	INAA
Ba	Barium	50	ppm	INAA
Br	Bromine	0.5	ppm	INAA
Ce	Cerium	5	ppm	INAA
Co	Cobalt	2	ppm	AAS
Co	Cobalt	5	ppm	INAA
Cr	Chromium	20	ppm	INAA
Cs	Cesium	0.5	ppm	INAA
Cu	Copper	2	ppm	AAS
Eu	Europium	1	ppm	INAA
Fe	Iron	0.02	pct	AAS
Fe	Iron	0.2	pct	INAA
Hf	Hafnium	1	ppm	INAA
La	Lanthanum	2	ppm	INAA
LOI	Loss-on-ignition	1.0	pct	GRAV
Lu	Lutetium	0.2	ppm	INAA
Mn	Manganese	5	ppm	AAS
Mo	Molybdenum	2	ppm	AAS
Na	Sodium	0.02	pct	INAA
Ni	Nickel	2	ppm	AAS
Pb	Lead	2	ppm	AAS
Rb	Rubidium	5	ppm	INAA
Sb	Antimony	0.1	ppm	INAA
Sc	Scandium	0.2	ppm	INAA
Sm	Samarium	0.1	ppm	INAA
Ta	Tantalum	0.5	ppm	INAA
Tb	Terbium	0.5	ppm	INAA
Th	Thorium	0.2	ppm	INAA
U	Uranium	0.2	ppm	INAA
U	Uranium	0.2	ppm	NADNC
W	Tungsten	1	ppm	INAA
Yb	Ytterbium	1	ppm	INAA
Zn	Zinc	2	ppm	AAS
Sample Wt	Sample weight	0.01	gram	-
WATERS:				
F-W	Fluoride	20	ppb	ISE
pH	Hydrogen ion activity	-	-	GCM
U-W	Uranium	0.01	ppb	FT

AAS - atomic absorption spectrometry
FT - fission track
GCM - glass Calomel electrode and pH meter
GRAV - gravimetry
INAA - Instrumental Neutron Activation Analysis
ISE - ion selective electrode
NADNC - neutron activation – delayed neutron counting

COMPARISON OF DATA PRODUCED BY TWO METHODS

A comparison of data generated by two different analytical methods can be made for a number of elements. Before attempting such a comparison some caution should be exercised.

- The original data for Co, As, and Fe were obtained by atomic absorption spectrometry using a partial extraction (HNO3 and HCl). The data for these elements obtained on re-analysis are by INAA, which produces 'total' data. Hence, the original data will likely be somewhat lower than the INAA data.

- The data for U were derived by a 'total' method, both originally and on re-analysis.

- The sample preparation for the original analyses differed from the preparation employed for the re-analysis. Originally, a portion of the collected sample was prepared. Prior to re-analysis the entire remaining original sample was prepared and bottled. As a result, most of the original data were obtained from a different split of the unprepared sample than that which was used for re-analysis. Disagreement between original and re-analyzed data for some elements might be attributed to heterogeneity of the two different splits used for the two analyses.

PRESENTATION AND INTERPRETATION OF GOLD DATA

The following general discussion reviews the format used to present the gold geochemical data and outlines some important points to consider when interpreting this data. This discussion is included in recognition of the special geochemical behaviour and mode of occurrence of gold in nature and the resultant difficulties in obtaining and analysing samples which reflect the actual concentration level at a given site.

The correct interpretation of gold geochemical data from regional stream sediment or lake sediment surveys requires an appreciation of the unique chemical and physical characteristics of gold and its mobility in the surficial environment. Key properties of gold that distinguish its geochemical behaviour from most other elements (Harris, 1982) include:

- Gold occurs most commonly in the native form, which is chemically and physically resistant. A significant proportion of the metal is dispersed in a micron-sized particulate form, and the high specific gravity of gold results in a heterogeneous distribution, especially in stream sediment and clastic-rich (low LOI) lake sediment environments. In organic-rich fluviatile and lake sediments, gold distribution appears to be more homogeneous.

- Gold typically occurs at low concentrations in the ppb range. Whereas gold concentrations of only a few ppm may represent economic deposits, background levels in stream and centre-lake sediments seldom exceed 10 ppb, and commonly are near the detection limit of 2 ppb.

These factors result in a particle scarcity effect wherein very low concentrations of gold are heterogeneously enriched or depleted in the surficial environment. Hence, a major problem facing the geochemist is to obtain a representative sample. In general, in areas where concentrations of gold in sediments are low, and/or grain sizes of the gold present relatively high, proportionally larger samples are required to reduce the uncertainty between subsample analytical values and actual values. Conversely, as actual gold concentrations increase or grain size decreases, the number of gold particles to be shared in random subsamples increases and variability of results decreases (Clifton et al., 1969; Harris, 1982). The limited amount of material collected during the rapid, reconnaissance-style regional surveys and the need to analyse for a broad spectrum of elements, precludes the use of a significantly large sample weight for the gold analyses. Therefore, to obtain representative samples, sieving and milling of the dried sediments reduce grain size. The following control methods are currently employed to evaluate and monitor the sampling and analytical variability, which are inherent in the analysis of gold in geochemical media.

For each block of 20 samples:

- random insertion of a standard reference sample to control analytical accuracy and long-term precision;

- collection of a field duplicate (two samples from one site) to measure sampling and analytical variance;

- analysis of a second subsample (blind duplicate) from one sample to measure and control short-term precision or analytical variance.

To provide additional information on gold data, samples with gold concentrations greater than or equal to 8 ppb were rerun by splitting the irradiated material into two portions (AuS1 and AuS2), each of which was re-irradiated and counted. Two additional analyses returning similar values suggest a finely divided and/or organically bound source for the gold. Two splits with distinctly different values probably contain larger gold grains unequally distributed throughout the original sample (the ‘nugget’ effect).

In summary, geochemical follow-up investigations for gold should be based on a careful consideration of all geological and geochemical information, and especially a careful appraisal of gold geochemical data and its variability. In some instances, pathfinder element associations in favourable geology may indirectly identify prospective follow-up areas, although an analogous gold response due to natural variability may be lacking. Once an anomalous area has been identified, field investigations should by designed to include detailed geochemical follow-up surveys and collection of large representative samples. Subsequent repeat subsample analyses will increase the reliability of results and permit a better understanding of natural variability which can then by used to improve sampling methods and interpretation.

DATA PRESENTATION

For this report, relative concentrations of selected elements in sediments at sample sites are illustrated with two types of images: shaded contour plots and multi-element proportional spot plots (‘beachball’ plots).

Contour plots depict broad regional trends. From the irregular grid of sample sites, a regular grid is generated using the following parameters:

Inverse Distance Weighting (IDW) function
Exponent = 1
Cell size = 1000 metres
Search radius = 15000 metres
Display Radius = 7500 metres

The resulting grid is then coloured based on percentiles. A hill-shading effect is also added to enhance the surface of the regular grid. Maps are generated using the Vertical Mapper® module in ©MapInfo.

'Beachball' plots, a variation of proportional spot plots, represent multi-element anomalies at specific sites. Individual analytical values of selected elements are reassigned with integer 'scores' of four, three, two, one or zero, depending on the relative position of each analytical result relative to the median value for each element. For example, values greater than 8.0 times the median value for an individual element might be assigned a score of four. Values greater than 5.0 times and less than or equal to 8.0 times the median value might be assigned a score of three, values greater than 3.0 times and less than or equal to 5.1 times the median value assigned a score of two. Values greater than 2.0 times the median value and less than or equal to 3.0 times the median value might be assigned a score of one, and values less than or equal to two times the median value assigned a score of zero. **Specific scores assigned to element ranges are found on individual maps.**

The total score is used to establish the size of the individual spot, with the maximum size of the spot equivalent to the composite score of the different elements represented. The proportion of the total value within individual spots represented by one element (elements are assigned different colours) is indicated by the size of the wedge within the spot. Bedrock geology maps are used as a background to facilitate a visual evaluation of the relationship between geology and element distribution.

GEOLOGICAL BACKGROUND

A geological base map was prepared by digitising a map of central Baffin geology compiled by Tippett (1984). Additional information on the Bravo Lake Formation was derived from Wheeler, et al. (1997). Morgan (1983) provided details of the geology of the Gillian Lake mapsheet (NTS 37D). A digital version of Morgan's map was obtained from a central Baffin geoscience compilation prepared by de Kemp and Scott (1998).

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Becquerel Labs, Ltd., Streetsville, Ontario provided reanalysis data, under the direction of P.W.B. Friske.

S.W. Adcock provided software support for the preparation of data listings and statistical information.

FIELD DATA LEGEND

Table 2 describes the field and map information appearing on the following pages preceding the analytical data for each sample site.

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TABLE 2. Field Observations Legend

FIELD RECORD	DEFINITION	TEXT CODE
NTS MAP	National Topographic System (NTS): lettered quadrangle (1:250 000 scale) Part of sample number	 27B, 27C, 37A, 37D
Sample Number	Remainder of sample number: Year Field Crew Sample sequence number	 78 1,3 001-999
Rep Stat	Replicate status; the relationship of the sample to others within the analytical block of 20: Routine regional sample First of field duplicate Second of field duplicate	 00 10 20
Location	Geographic reference system; digitised sample locations from North American Datum of 1983 (NAD83) spheroid	
Latitude	Latitude (decimal degrees, positive values)	
Longitude	Longitude (decimal degrees, negative values)	
Geology Unit	Major rock type of lake catchment area: **PALEOZOIC** Undivided Paleozoic limestone and dolomite **Ordovician** ***Upper Middle and Upper Ordovician*** Dolomitic limestone; minor calcareous dolostone ***Upper Lower and Lower Middle Ordovician*** *Ship Point Fm.*: dolostone, sandy in part, silty, argillaceous dolomitic flat-pebble conglomerate; minor dolomitic sandstone, siltstone, breccia quartz-cemented sandstone **PROTEROZOIC** **Aphebian** Massive, fine- to coarse-grained, pink granite-granodiorite; chiefly quartz monzonite; abundant crosscutting veins and sheets of aplite and pegmatite; local weak foliation Massive, white muscovite-biotite granite-quartz monzonite Pegmatite; white to light grey: massive; includes some aplite and granite; may contain muscovite, biotite, garnet, tourmaline and beryl; chiefly sills and dykes but also crosscutting veins and sheets; local deformation and foliation; mapped and schematic bodies ***PILING GROUP*** Undivided Piling Group Metamorphosed iron formation; chiefly oxide facies with silicate facies; metallic grey; fine- to coarse-grained; laminated to bedded; includes quartzite, paragneiss, amphibolite and basic metavolcanic horizons *Longstaff Bluff Fm.:* greywacke, psammite, slate and metamorphic equivalents (schist, paragneiss, migmatitic paragneiss); interbedded; thin to thick bedded, light to dark grey; graded beds and typical turbidite structures; some rust schists; minor calc-silicate rocks *Astarte River Fm.*: sulphide schist; rusty weathering, graphitic, pyrrhotite-pyrite schist and slate; sulphide facies iron formation *Flint Lake Fm.*: dolomite, marble and calc-silicate gneiss; chiefly white to grey or buff weathering; minor paragneiss, quartzite and rusty schist *Bravo Lake Fm.*: mafic volcanics; amphibolites; hornblendites; tremolite-actinolite-rich schists; some ultramafics containing abundant olivine and clinopyroxenite *Dewar Lakes Fm.*: quartzite and feldspathic quartzite; grey, white and black; laminated, bedded and massive; includes muscovite schist, commonly with sillimanite, and paragneiss; some rusty horizons **ARCHEAN** ***MARY GROUP*** Meta-anorthosite-metagabbro; white to grey; banded to massive; foliated; fine- to coarse-grained; megacrysitic with local football anorthosite; cumulate textures; layers of amphibolite and hornblendite; foliated amphibolite dykes Slate, greywacke and metamorphic equivalents (schist, paragneiss, migmatic paragneiss); laminated to thick bedded; light to dark grey; rusty; minor impure quartzite, conglomerate, amphibolite and volcaniclastic rocks Mafic metavolcanics; chiefly migmatized amphibolite; dark grey, brown, green, black; fine- to medium-grained; foliated, banded or massive Quartzite; white to pale grey; thin bedded to massive; fine grained to very fine grained; sheared; cherty; Minor schist and paragneiss horizons; amphibolite sills; includes coarse cobble conglomerate with acid metavolcanic clasts and some quartzite Amphibolite and hornblende-gneiss dykes; medium- to coarse-grained; dark grey green to black; commonly foliated and banded	 P Os Ols Apgr Apbg Appm Appu Apif ApLB ApAR ApFL ApBL ApDL AMan AMpe AMmv AMqz Aam

	Ultramafic rocks; serpentinized peridotite and hornblendite; foliated to schistose; dark green or brown weathering	Aum
	Weakly mineral foliated quartz-monzonite-granodiorite; minor granite; pale pink to grey; medium- to coarse-grained	Agr
	Potash feldspar augen gneiss; quartz monzonite-granodiorite; grey to pink; streaky appearance; medium- to coarse-grained; pervasive mineral lineation	Aag
	Quartz monzonite-granodiorite gneiss; banded and foliated; medium- to coarse-grained; light grey to pink granitic bands alternate with darker more mafic bands	Agn
	Migmatite and nebulitic migmatite; chiefly massive; foliated thin banded, fluidal or streaky granitic to granodioritic gneiss; grey to pink; fine- to medium-grained; amphibolite and metasedimentary schlieren and nebulae common; local well-banded gneisses, mixed rocks and agmatite; may contain some Aphebian rocks	Amg
Geology Age	Stratigraphic age of dominant rock type of catchment area:	
	Paleozoic (undivided)	09
	Ordovician	15
	Aphebian	05
	Archean	02
	The area of the water body sampled:	
	Pond	pond
	1/4 to 1 square kilometre	0.25 – 1.0 sq km
	1 to 5 square kilometres	1 – 5 sq km
	greater than 5 square kilometres	>5 sq km
Lake Depth (metres)	Distance in meters from the surface of the lake to the bottom	0-99
Terrain Relief	Relief of lake catchment basin:	
	Low	Low
	Medium	Medium
	High	High
Sample Contam	Contamination; human or natural:	
	None	-
	Work	Work
	Camp	Camp
	Fuel	Fuel
	Gossan	Gossan
Sample Colour	Sediment sample colour; up to two colours may be selected:	
	Tan	Tan
	Yellow	Yellow
	Green	Green
	Grey	Grey
	Brown	Brown
	Black	Black
Suspended Material	Suspended matter in water:	
	None	-
	Heavy	Heavy
	Light	Light
Miscellaneous	Abbreviations appearing in listing:	
	missing data in any field	-
	no sample material for analysis	ns
	parts per million	ppm
	parts per billion	ppb
	percent	pct
	weight (of sample)	Wt
	gram	g